Experience of Hot Cell Renovation Work in ACPF (Advanced Spent Fuel Conditioning Process Facility)

21th, Oct. 2014

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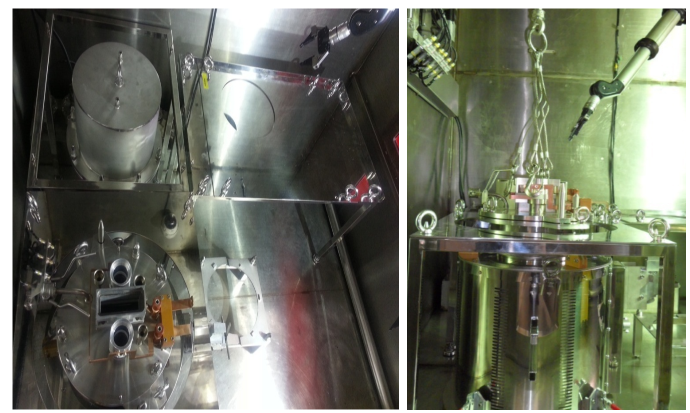
1. Introduction - ACPF (Advanced spent fuel Conditioning Process Facility)

- Purpose : Feasibility verification of an Electro-reduction process for PWR spent fuel in high-temp. molten salt
- General Features
  - History: Construction('03~'05), Inactive Test('06~'12), Refurbishment('13~'14), Test & Operation ('15~)
  - High shielded hot cell with a modular type Ar compartment : 11 x 2 x 4 (LxWxH) m
  - Remote handling system: Crane (1 set), MSM (5 sets) and Window workstations (5 sets)
  - Demonstration of electrolytic reduction process and enhancement of safeguard ability for electro lytic reduction process

Internal view of ACPF (Before & After refurbishment)



Electrolytic reducer & remote operability & maintainability test

2. Background and Necessity for ACPF Refurbishment

- Technical issues
  - Severe corrosion of oxide reducer (OR) by high-temperature salt & oxygen

    ➡ Needs Ar atmosphere for safe OR operation

  - Installation of small Ar compartment inside hot-cell

    ➡ Scale-down of the capacity of OR from 20 kgHM/batch to 1 kgHM/batch to accommodat e the OR in the Ar compartment

- Taking some unnecessary process equipments out of ACPF
  - Cramped hot cell space of ACPF due to the installation of Ar compartment
  - Taking smelter and waste salt treatment equipment out of the hot-cell
  - Closely related to and supported by the DFDF activities

    ➡ Decladding, off-gas trapping, and voloxidation in DFDF

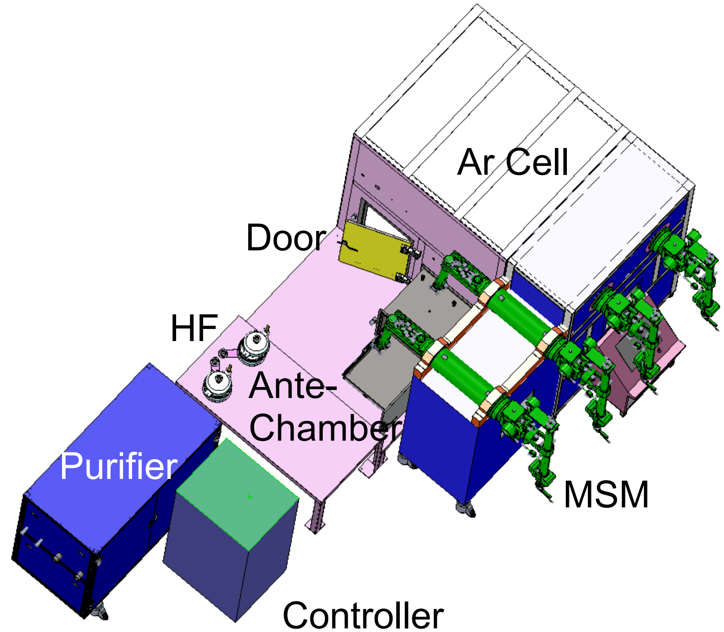
    ➡ Taking decladding, off-gas trapping, and voloxidation equipments out of the ACPF hot-c ell

3. General Characteristics of ACPF

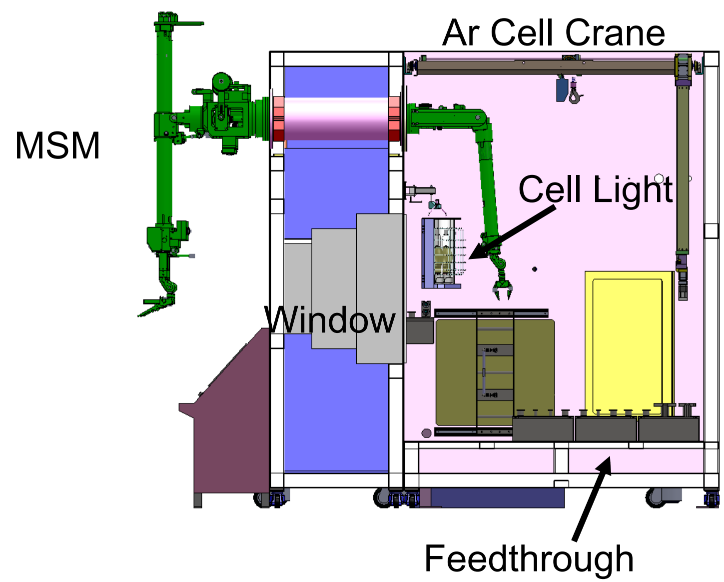
Construction Period	• Construction: 2004. 10 - 2005. 07 • IAEA Preliminary Design Information Submit: 2003. 10. 22 • Operating License Acquisition: 2005. 11. 04 • Performance Test: 2005. 12 - 2007. 02	
Hot Cells Inside Dimensions	Process Hot Cell	**8.1 mL x 2 mW x 4.3 mH♪**
	Maintenance Hot Cell	**2.2 mL x 2 mW x 4.3 mH♪**
Hot Cell Equipment	5 pairs MS Manipulators (Alpha-gamma tight), 1 Telescopic Manipulator, 5 Shielded Windows, 1 One ton In-cell Crane	
Wall Thickness, Radiation Shielding Material	90 cm, Heavy Concrete	
Main Process Equipment	Electrolytic Reducer	
Operator's Safeguards Equipment	ASNC, ASNM, Cameras	
Ar Compartment (Newly installed in M8a cell)	1.8 mL x 1.8 mW x 2.4 mH	
Normal Inventory	PWR Spent Fuel : 10 kgU ※ NU/DU including surrogate materials for cold test : 8 kgU	
Annual throughputs	10kgU of PWR spent fuel/year	
Max. Quantity of Nuclear Material	PWR Spent Fuel : 100 kgU Fresh NU/DU: 8 kgU(for cold test)	

4. Design of Argon Mock-up System

- Performance Verification using the ACPF Argon Cell Mock-Up system
  - Argon cell pressure control
  - Installed ante-chamber, crane, utility.
  - Verification of the Material Transportation performance using the cell equipments
  - Operability and maintainability of electro reduction facility

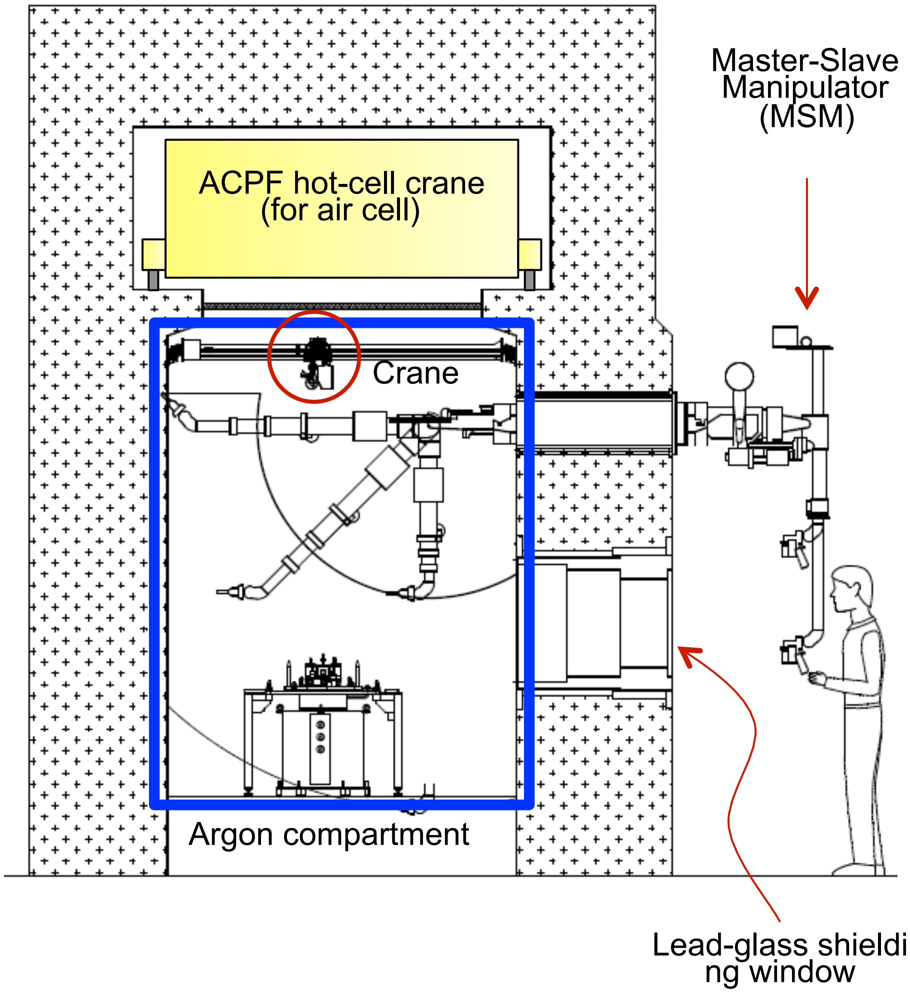


- Specifications of Argon Cell Mock-up System
  - Ar Cell Size : 1,800 x 2,000 x 3,270 (L x D x H)
  - Door Size : 600 x 1,000 (L x H)
  - Ante-Chamber Container Size : 600x600x600 (LxDxH)
  - Transported material using Ante-Chamber : 100 kgf
  - Payload of Ar Cell Crain 150 kgf
  - Work space: 1,500x1,450x2,800 (LxDxH)

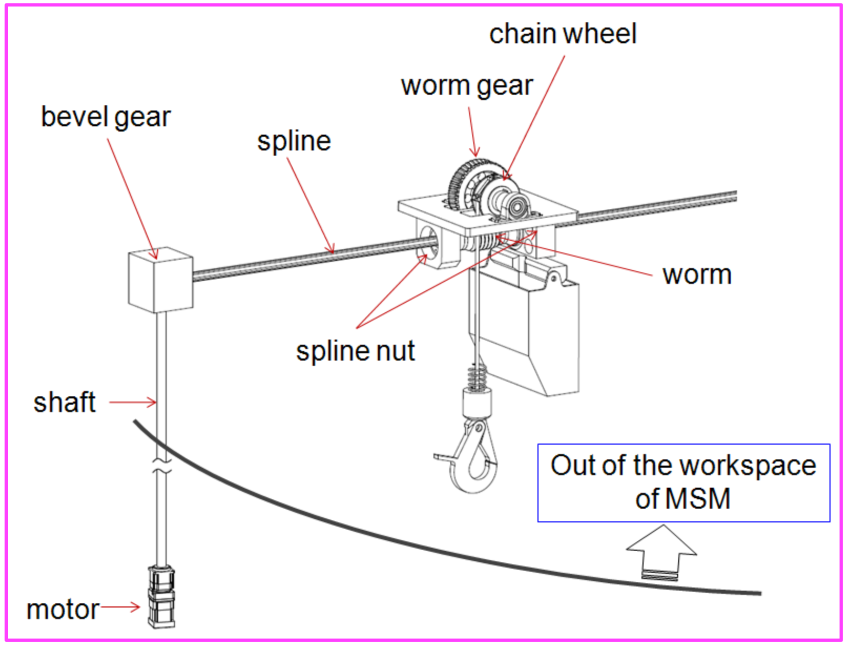


4. Design of Argon Mock-up System

- Development of Robotic Crane System for Argon Compartment



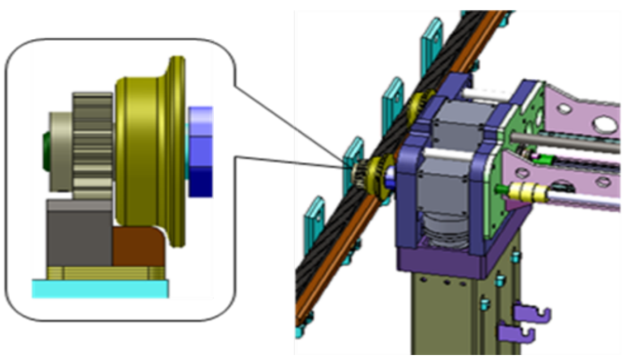
Conceptual design of an argon compartment



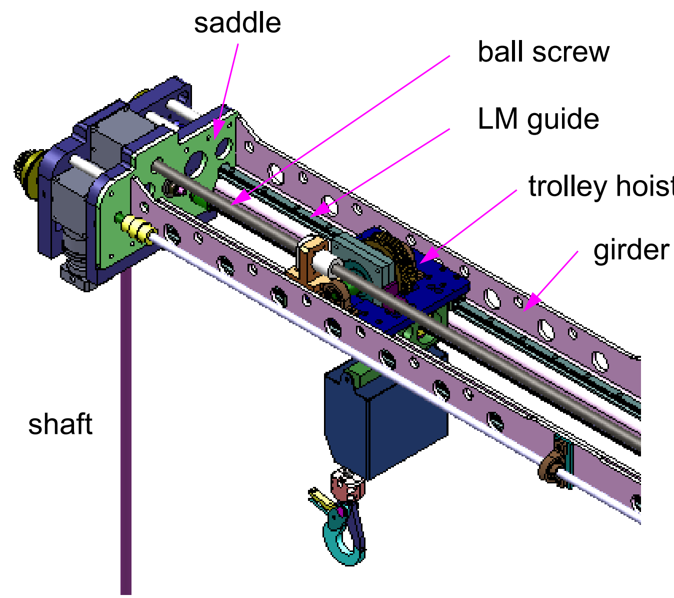
- Process equipment operation
  - Anti-slip and anti-sway driving is applied for safe and accurate movement

4. Design of Argon Mock-up System

- Anti-slip driving mechanism
  - To provide accurate motion and absolute positioning,
    - Traveling: combination of wheel(support of load) and rack-pinion(anti-slip), secondary guide roller for preventing rollover, shim plate for leveling
    - Traversing: ball screw and LM guide
    - Hoisting: ball spline
  - Small amount of friction



Traveling



Traversing

4. Design of Argon Mock-up System

- To increase the durability of mechanical parts
  - Use of commercially proven components(ball-screw, ball spline, LM, etc) so as not to be bro ken within the expected life time of the crane system.
  - Important factors for selection: critical speed, nominal life, etc.

- Selection of ball-spline (example)
  - Critical speed: 600 RPM(related to resonance), 200 RPM(max. operating RPM), used for th e selection of gear ratio.
  - Nominal life: 17.1 years for the given operating parameters, such as a stroke length of 1.5 m , and one stroke per minute with nearly max. speed, 8 hours working per day.

Critical speed

$$N_c = \frac{60\lambda^2}{2\pi \cdot l_b^2}\sqrt{\frac{E \times 10^3 \cdot I}{\gamma \cdot A}} \times 0.8$$

$$= 600 \text{ RPM}$$

λ : mounting method (support-support condition)

l_b : distance between two mounting surfaces

Nominal life (torque dominant)

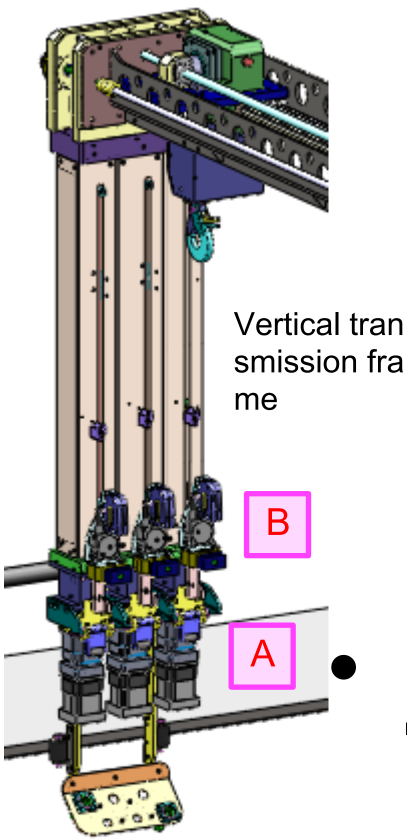
$$L = \left(\frac{f_T \cdot f_C}{f_W} \cdot \frac{C_T}{T_c}\right)^3 \times 50 = 9.0 \times 10^3 \text{ km}$$

Lifetime

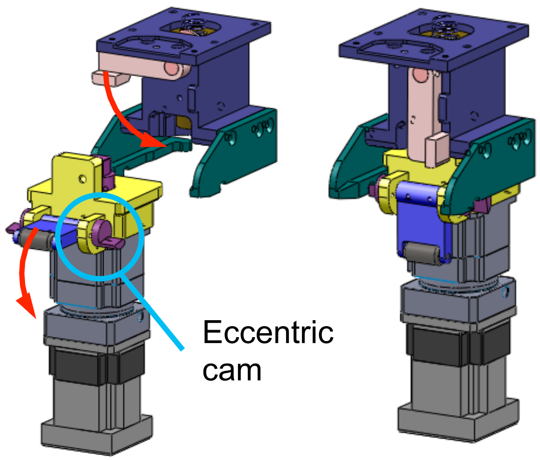
$$L_h = \frac{L \times 10^3}{2 \times l_s \times n_1 \times 60} = 17.1 \; years$$

$l_s = 1.5\, m$: stroke length $n_1 = 1$: # of stroke per minute

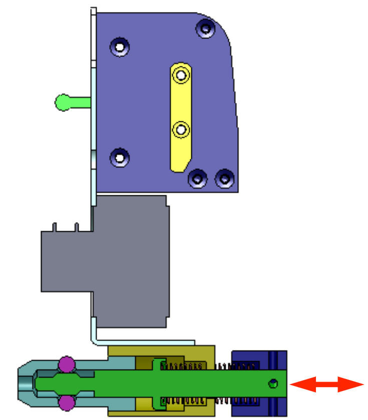
4. Design of Argon Mock-up System



A Drive module



B Sensor module

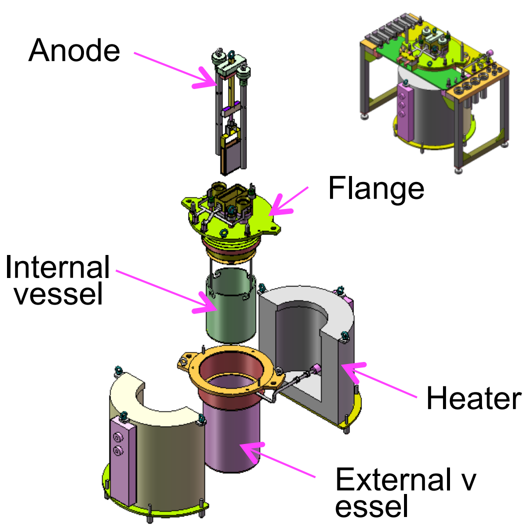


- Drive module
  - Requirements: 1) firmly fixed to the frame while connecting the transmission sh aft to the motor shaft 2) easily separable from the frame in a remote manner
  - Design: a lever for shaft separation, cam clamping mechanism

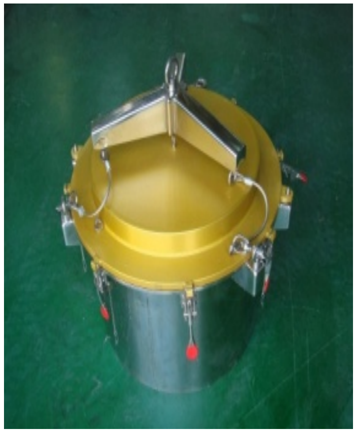
- Sensor module
  - Consists of two limit switches and a wire sensor
  - Ball spring mechanism is used to ease the mechanical attachment/detachment

4. Design of Argon Mock-up System

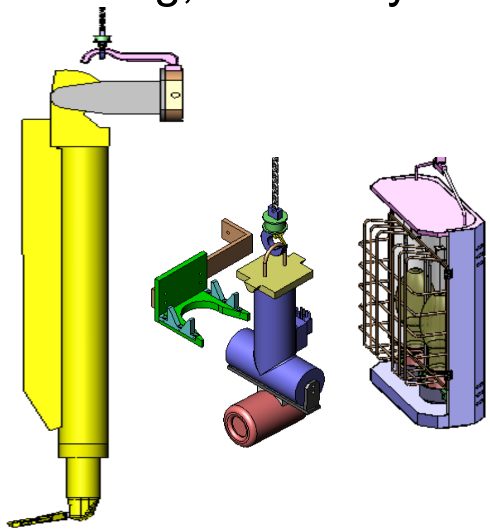
- Robotic Crane applications include
  - Remote operation of modularized process equipment
  - Transportation: materials, casks, products
  - Remote maintenance: process equipment module, MSM, camera, cell light, sensors, etc.
- Safe and absolute movement is desirable
  - Calibration of process equipment
  - Sequential/automatic operation based on absolute positioning; anti-sway control



Process Equipment



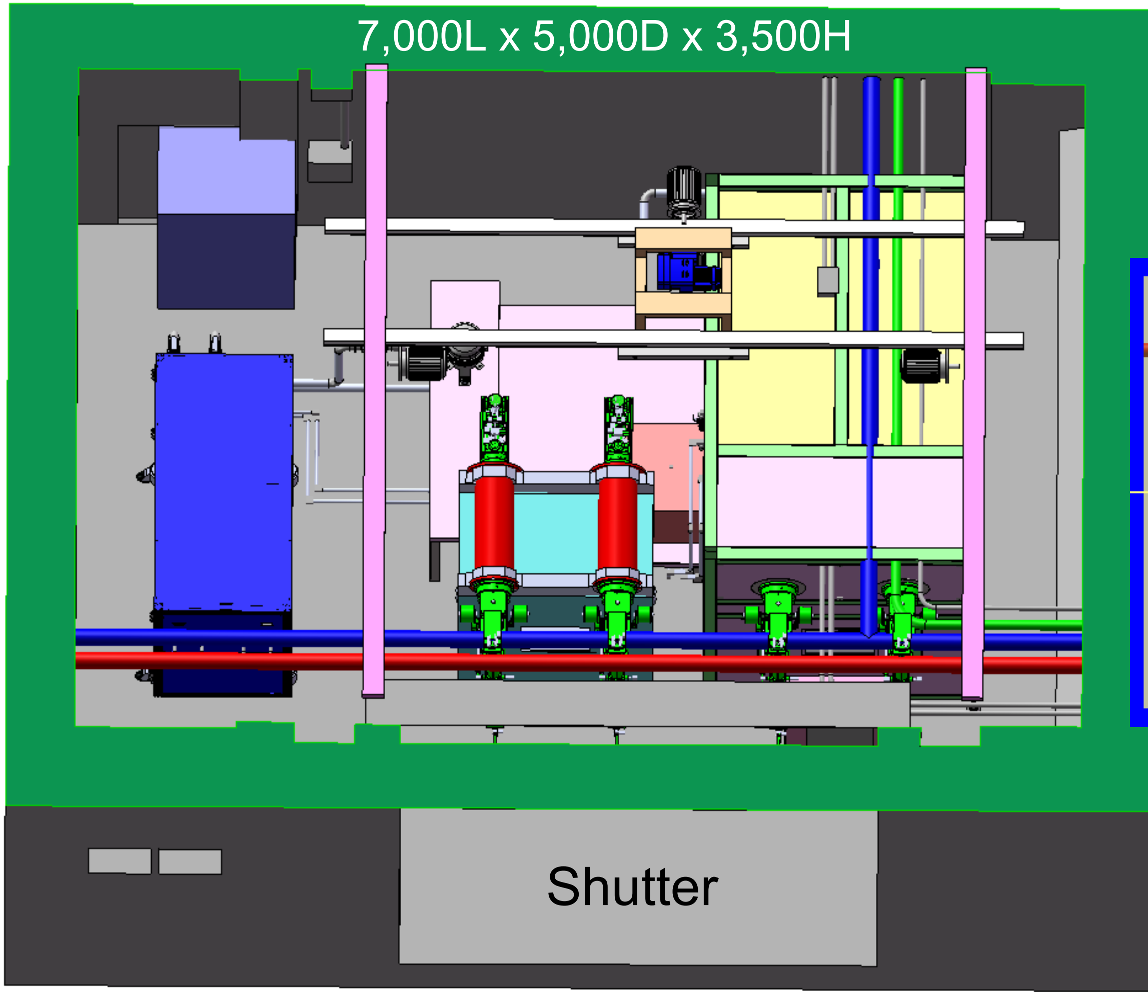
Cask & Container



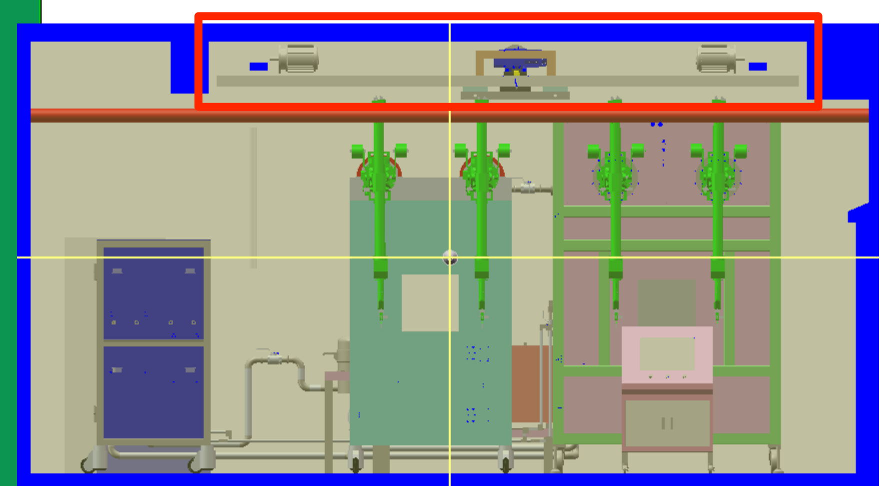
Manipulator / Camera / Light System

4. Design of Argon Mock-up System

- General Layout of Argon Mock-up System

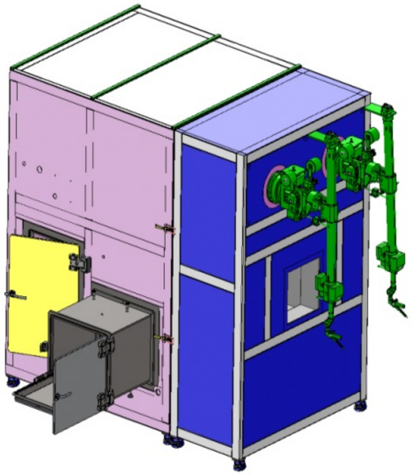


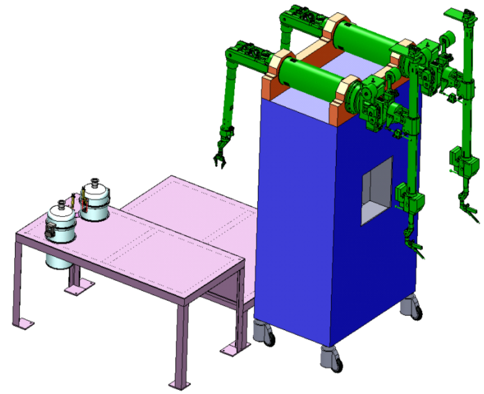
1 Ton Overhead Crane



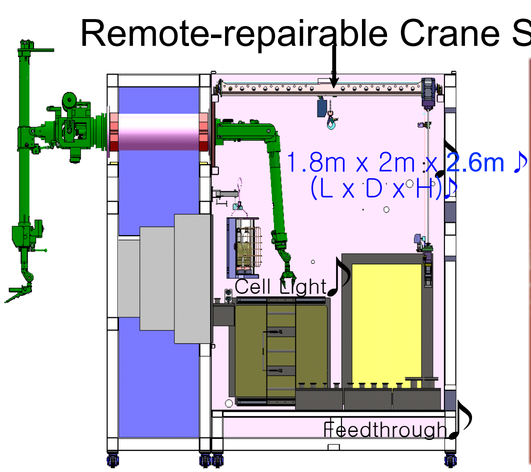
5. Development of Argon Mock-up System

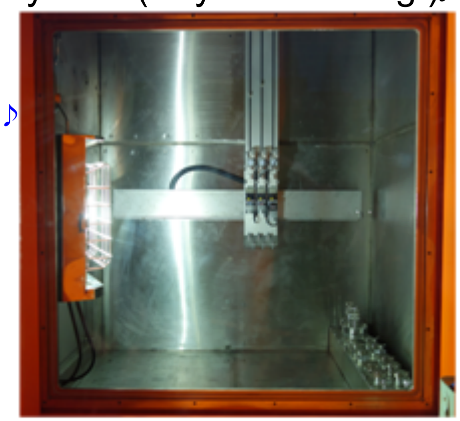
- Ar Compartment Mock-up



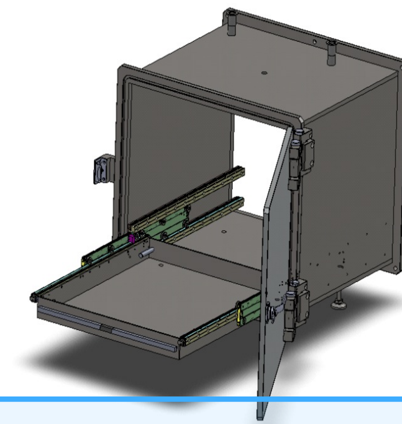


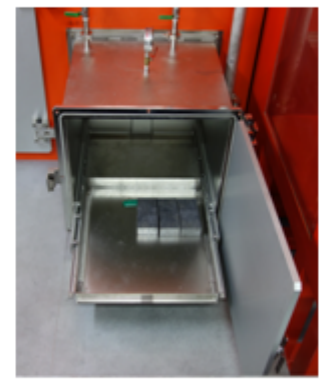
[External view]





[Internal view]



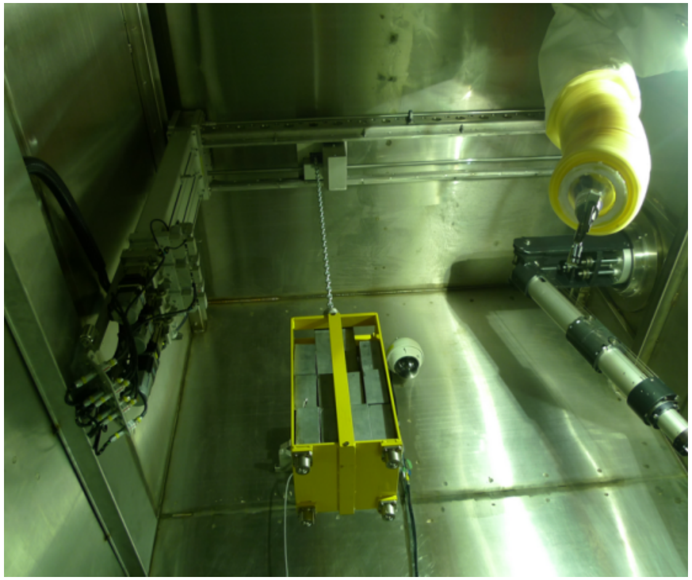


Ante-chamber for mid-weight material handling

- Opening/closing door and sliding tray
- Rectangular type, mechanical door lock
- Allowable movable weight : 100 kgf
- Allowable material size : 600 x 600 x 600 (L x D x H)

5. Development of Argon Mock-up System

Constructed Ar compartment

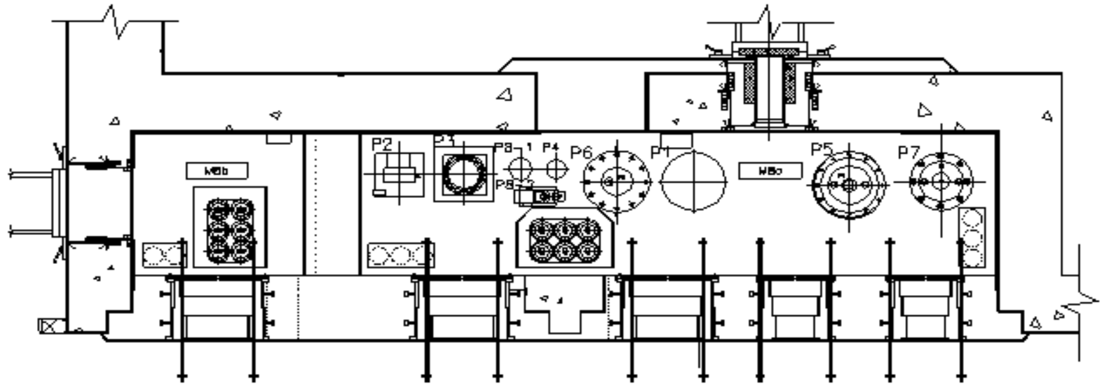


Mock-up system

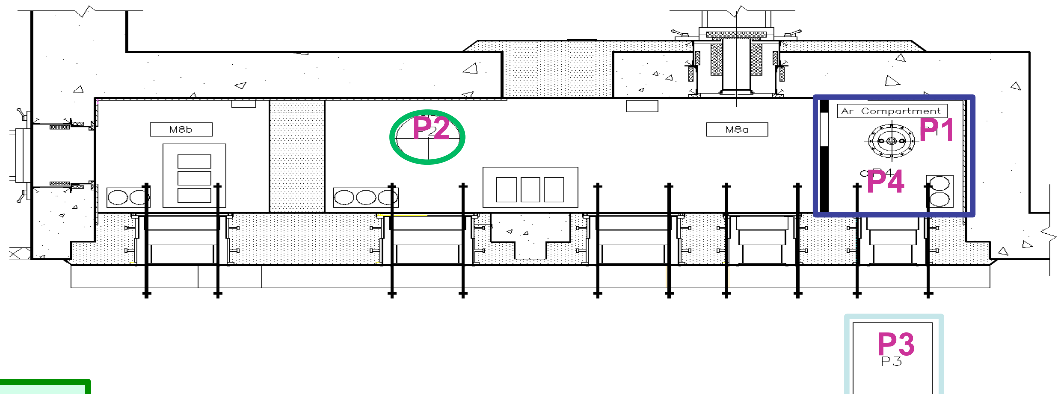
Remote controllability test of installed equipment inside Ar compartment

5. ACPF Renovation

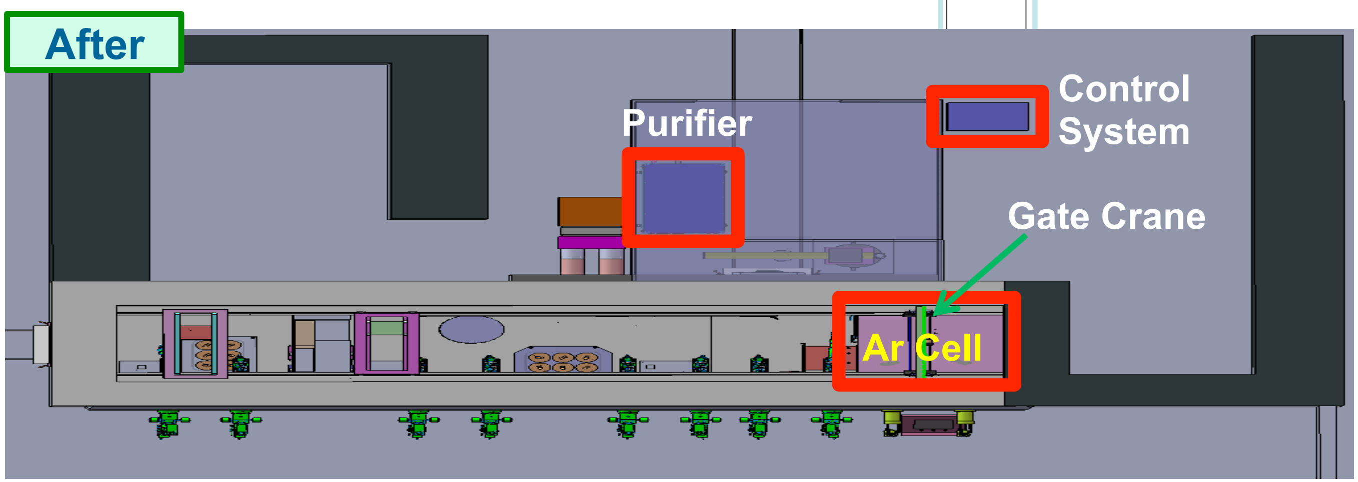
- Previous Layout



- New Layout after refurbishment



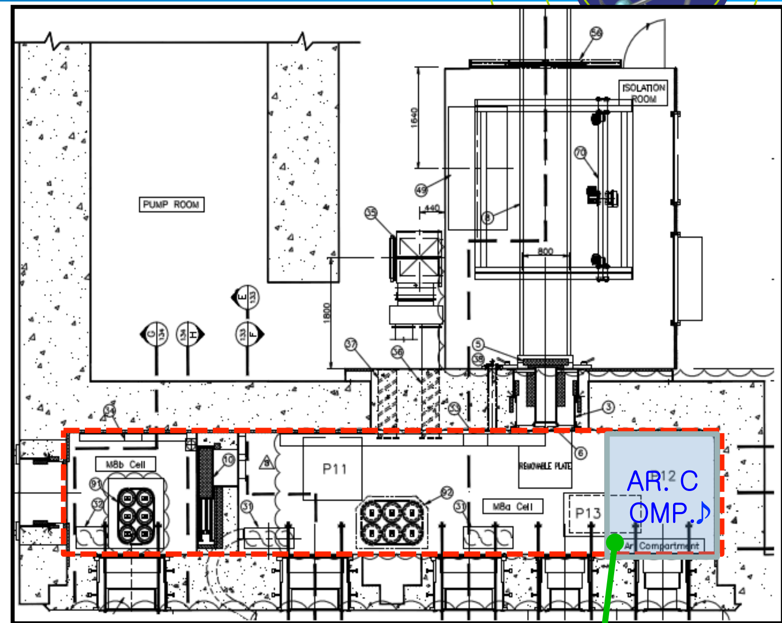
P1. Electrolytic Reducer♪
P2. ASNC♪
P3. FOLIBS system
P4. Remote Probe of FOLIBS system

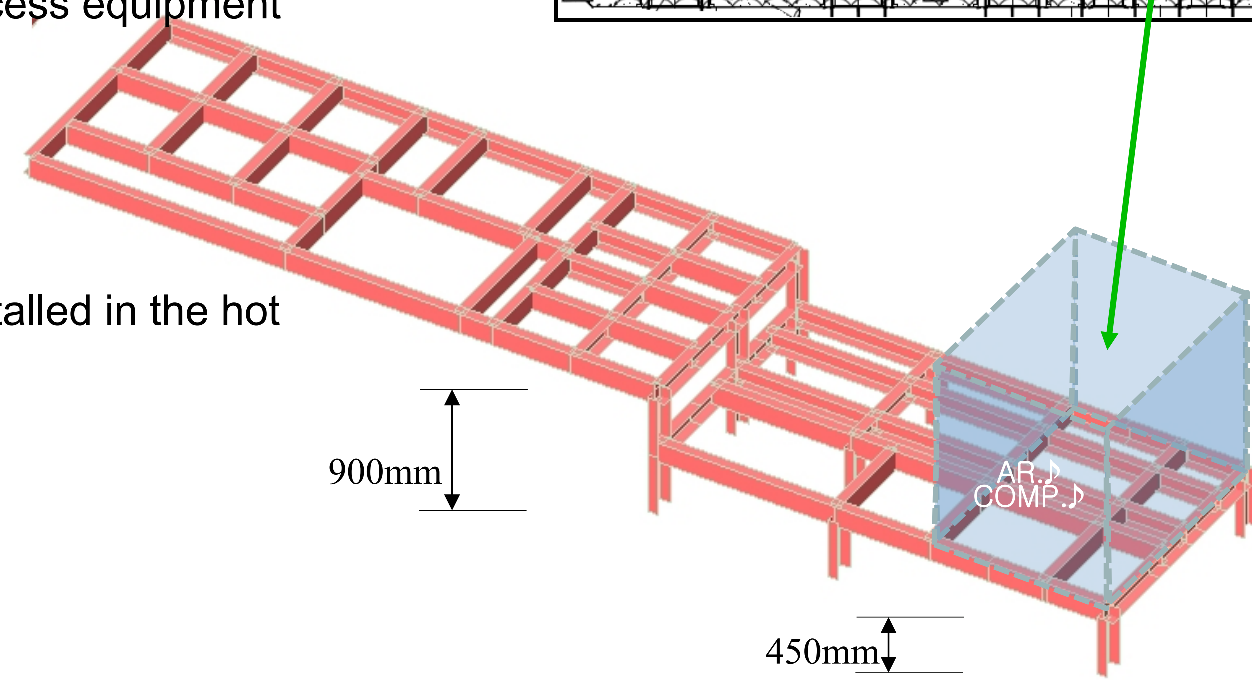


5. ACPF Renovation – Preliminary Survey

- Reconfiguration of working table

  - The level of W/T was changed from 900mm to 450mm for the installation of Argon compartment.
  - Robotic Crane was newly installed in the Argon compartment to handle the process equipment and utilities precisely.
  - Other new equipments were installed in the hot cell.

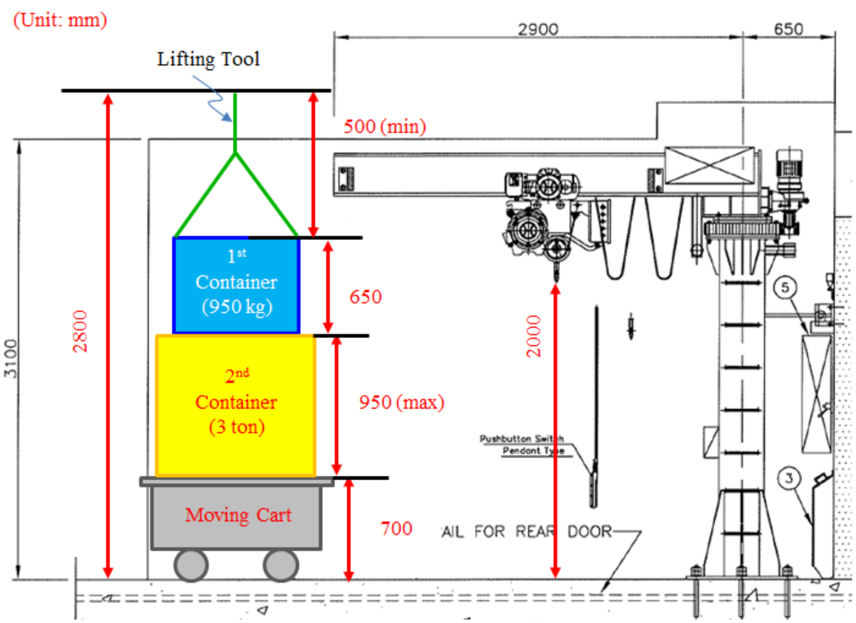




5. ACPF Renovation – Preliminary Survey

Renovation of Crane System

- A jib crane was installed and operated in the old ACPF isolation room, but the lift height of this jib crane wa s not sufficient to accommodate the new shielded containers.
- The second shielded container is a extremely heavy container that cannot be loaded off the transport cart, and it posed a challenging problem that it could not be handled with the jib crane inside the isolation room. Even if the second container could be taken off the trolley, it still involved the constraint of fabricating the lif t chain in ~400 mm length.



[Newly Proposed Shielding Container] [Current Jib Crane System]

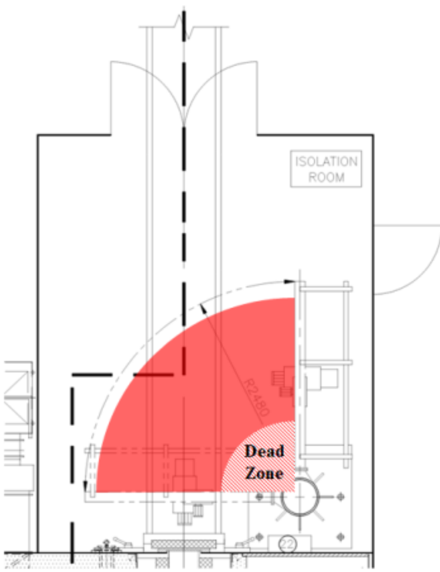
Finally, the issue for the Increase of the lifting h eight was raised and redesigned the crane syst em of the isolation room of ACPF.

5. ACPF Renovation – Preliminary Survey

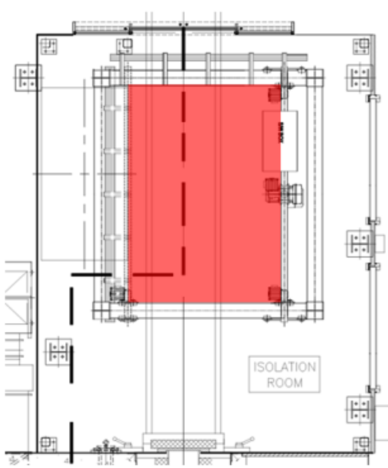
● Renovation of Crane System

- To address these problems, we increased the overall height of the isolation room ceiling in the ne w design, thereby modifying the old jib crane into a gantry crane.

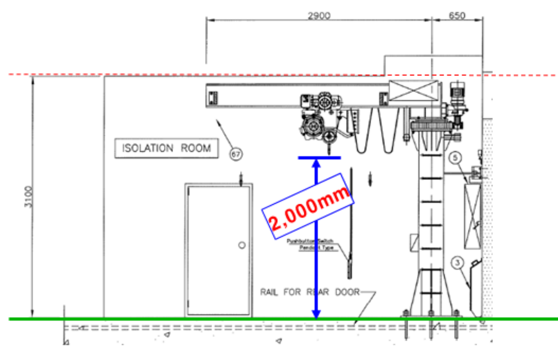
- The new gantry crane outperformed the old jib crane in lift height by ~63.5% while retaining ~94% coverage of old crane system.



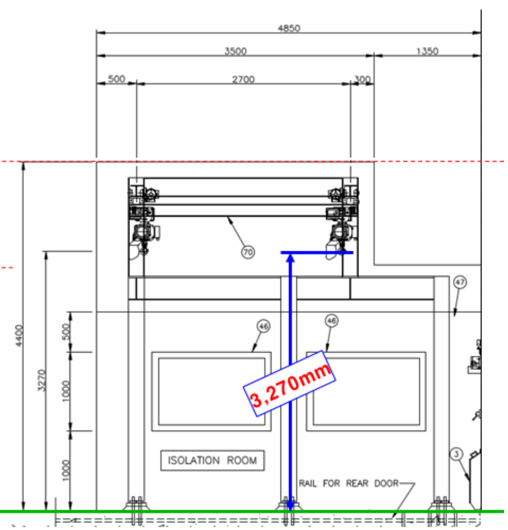
[Before Renovation]



[After Renovation]



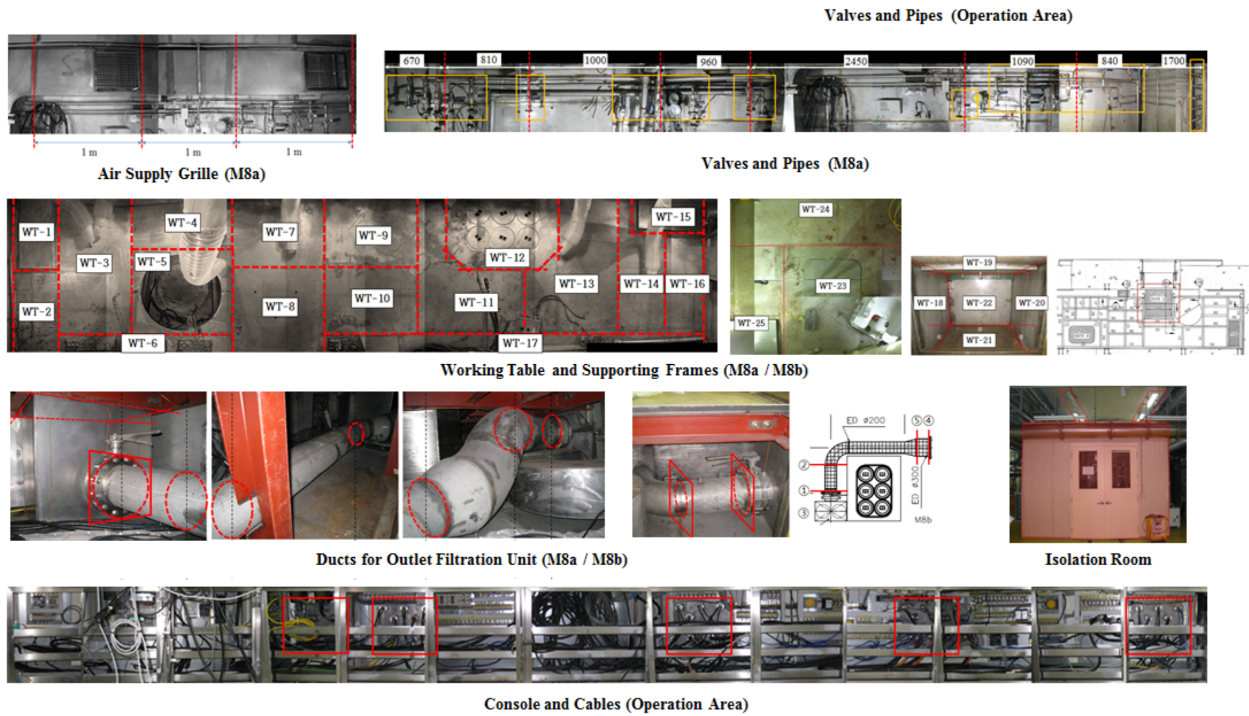
[Before Renovation]



[After Renovation]

5. ACPF Renovation – Decontamination

- Prior to disassembly task, decontamination tasks were performed.
- The contamination analysis results were assessed by zone, and a second salt removal was performed on the zones that needed further decontamination.



5. ACPF Renovation – Disassembly and Removal Work

Container Preparation

Disassembly of power system

Preparatory facility work (site prote ction and safety check)

Facility disassembly (operation area)

Facility disassembly (hot cell area)

Waste material sortin g and stacking

Delivery the waste to the dis posal site

Completion of hot cell disassembly

5. ACPF Renovation – Installation of New Facility

- Many parts of existing processing equipments were removed and the newly designed Ar co mpartment is constructed within the hot cell.
- Uninterruptible power supply system newly installed.
- Now, performance test for the HVAC and utility system are carrying on.

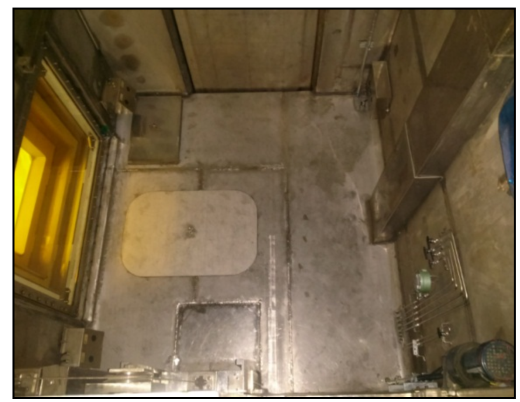
Pre- and post-renovation hot cell interior

5. ACPF Renovation – Installation of New Facility


Argon Compartment System



M8a Cell



M8b Cell

5. ACPF Renovation – Installation of New Facility

- Process equipment and other supplementary facilities within the hot cell can be operated using the re mote-control system.

- A UPS system and a new automatic control-based Ar supply system also have been installed in the o peration area. Work convenience have been increased by wireless communication tools instead of th e tethering-based one for the hot cell crane operation system

Post-renovation modifications made in ACPF operation area: automation of power-supply system of Ar c ompartment, wireless communication of crane system, UPS system ensuring stable power supply even during facility power-off hours

6. Conclusions and considerations

- During disassembly in the hot cell, we could minimize workloads while keeping the fugitive dust and contami nants at the lowest possible levels through differentiated packaging of the dismantled materials according to size before transportation.

- Radiation levels in the hotcell facility could also be minimized through systematic decontamination process a nd contamination analysis through prior zoning and coding of all disassembly objects. Furthermore, individu al irradiation amounts of all workers were monitored daily using protection device sampling and personal rad iation dosimeters, and their working hours were regulated by setting up rotating shift work schedules.

- Safe waste management was ensured by performing in advance multi-aspect decontamination measures su ch as smear test, post-packaging surface radiation level test, and component analysis of sampled waste mat erials.

- Possible errors during renovation were prevented by performing mock-ups of new facilities and 3D-image simulation and by proactively applying the results to the actual work.

- Based on the results of the renovation work, it is considered critical to perform sufficient preliminary investigation and verification to prevent accidents at the sites.

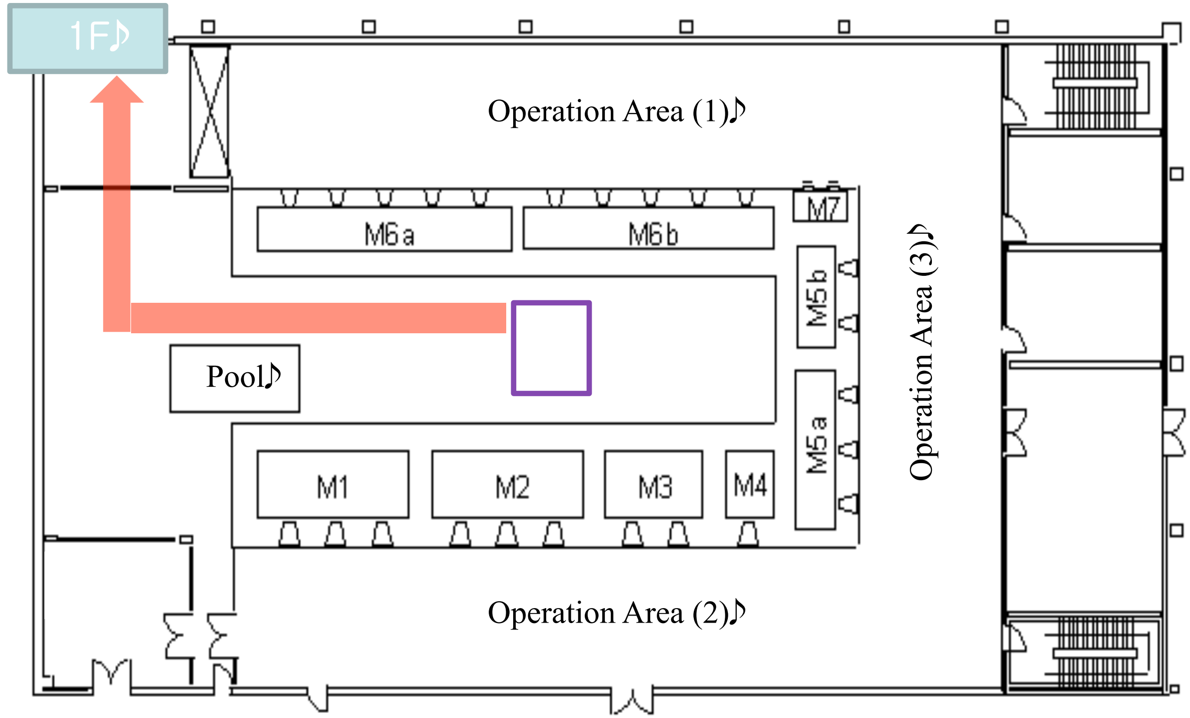
- Specifically, mock-ups should be employed to ensure proper handling of actual facilities and devices. This system is useful to perform the sufficient preliminary measures while considering the unexpected on-site situations.

7. Summaries and Future Works

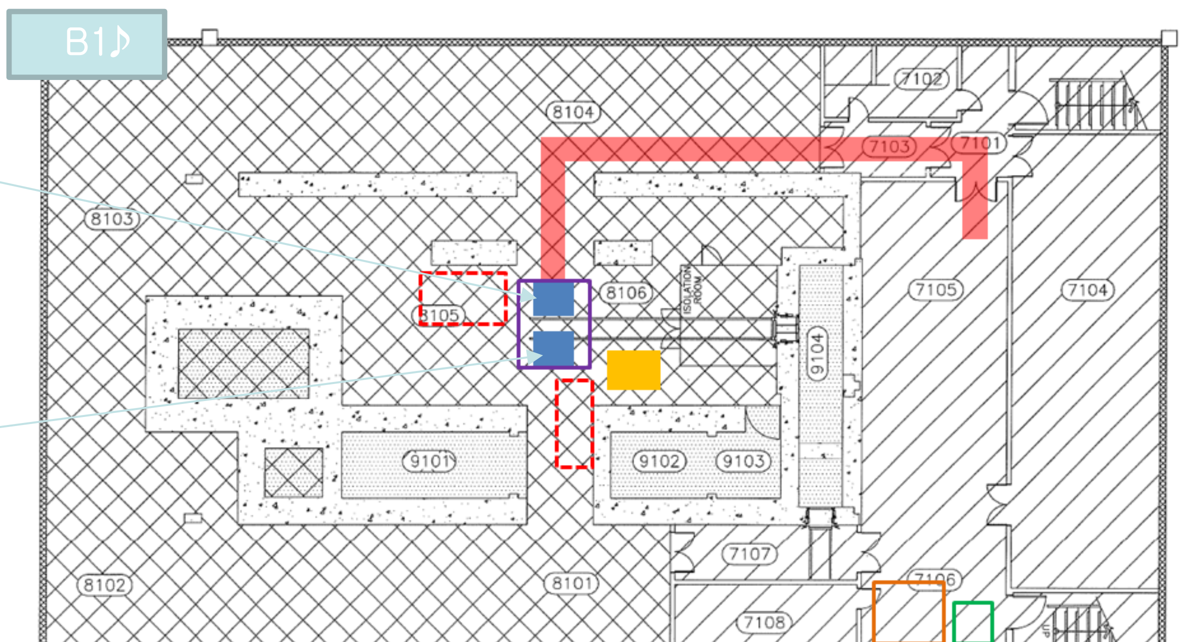
- Current status of ACPF
  - Facility description
    - 1 work station : Ar compartment equipped with electrolytic reducer
    - 3 work stations : Air environmental cell equipped with rear door, storage vault, and ASNC
    - 1 work station : Air environmental cell for maintenance of hot cell equipment
  - Future R&D Plans
    - Key technology development for electrolytic reduction process for PWR spent fuel
      - Analyzing electrochemical behaviors : Potential behaviors of electrodes, Reduction yields of U, TRU, NMs, and Electrochemical behaviors of FPs
      - Assessment of reducer system : Stability of reducer system, Remote operability and maintain ability
    - R&D to improve safeguard ability for electrolytic reduction process
      - Demonstration of ASNC(ACP Safeguards Neutron Counter)
      - Study of LIBS(Laser-Induced Breakdown Spectroscopy Instrumentation) : Optimization of FO LIBS to maximize the signal/noise ratio, LIBS analysis on pellets(or granule) and reduced spe nt fuel

Thank you

Appendix

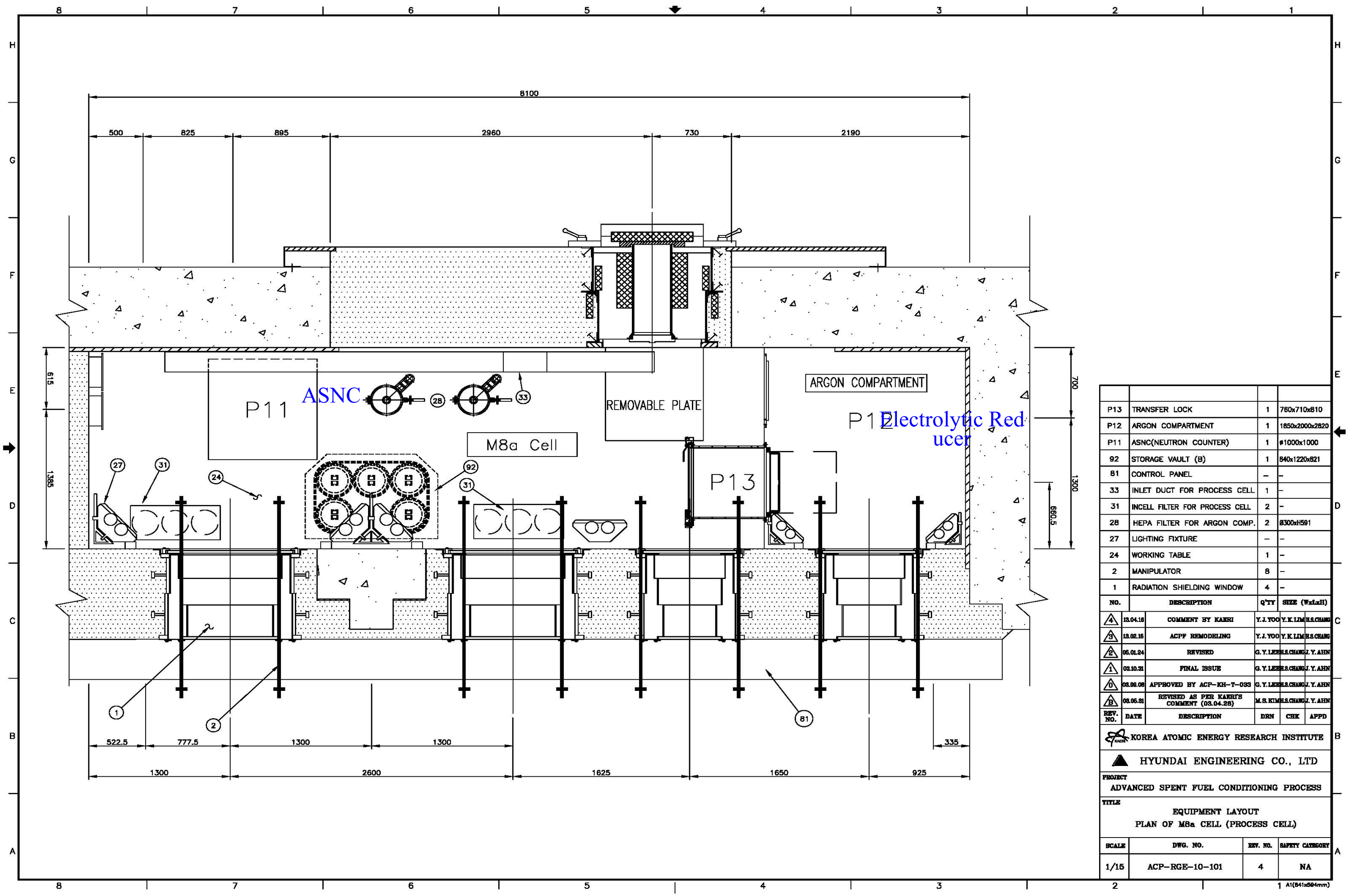


1F
Operation Area (1)
M6a
M6b
M7
M5b
M5a
Operation Area (3)
Pool
M1
M2
M3
M4
Operation Area (2)



B1
7102
8104
7103
7101
8103
8106
8105
ISOLATION ROOM
7105
7104
9104
9101
9102
9103
7107
7106
8102
8101
7108

After the Renovation



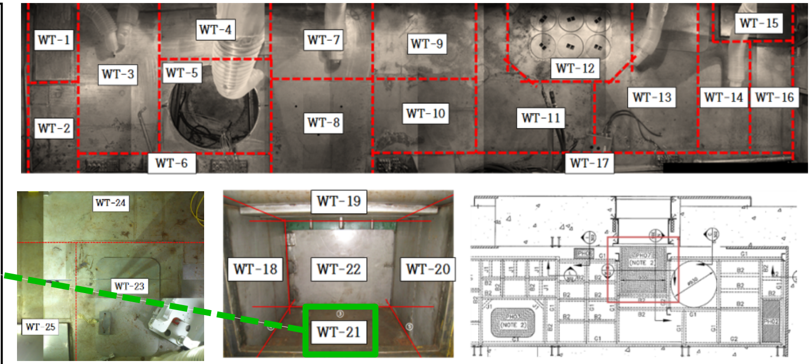
Process of Smear Test

기존시설 철거 관련 Smear Test 목록 (ACPF)

붉은색 Cell: 12일 테스트 실시
푸른색 Cell: 14일 테스트 실시

No.	Index	Type	Location	Smear Test Result
1	D-1	Duct	M8a	
2	D-2	Duct	M8a	
3	D-3	Duct	M8a	
4	D-4	Duct	M8a	
5	D-5	Duct	M8a	
6	D-6	Duct	M8a	
7	D-7	Duct	M8a	
8	D-8	Duct	M8a	
9	D-9	Duct	M8b	
10	D-10	Duct	M8b	
11	D-11	Duct	Isolation Room	
12	V-1	Valve	M8a	
13	V-2	Valve	M8a	
14	V-3	Valve	M8a	
15	V-4	Valve	M8a	
16	V-5	Valve	M8a	
17	V-6	Valve	M8a	
18	P-1	Pipe	M8a	
19	P-2	Pipe	M8a	
20	P-3	Pipe	M8a	
21	P-4	Pipe	M8a	
22	P-5	Pipe	M8a	
23	P-6	Pipe	M8a	
24	P-7	Pipe	M8a	
25	P-8	Pipe	M8a	
26	P-9	Pipe	Service Area	Canceled
27	P-10	Pipe	Service Area	Canceled
28	P-11	Pipe	Service Area	Canceled
29	P-12	Pipe	Service Area	Canceled
30	P-13	Pipe	Service Area	Canceled
31	P-14	Pipe	Service Area	Canceled
32	P-15	Pipe	Service Area	Canceled
33	WT-1	Working Table	M8a	
34	WT-2	Working Table	M8a	
35	WT-3	Working Table	M8a	
36	WT-4	Working Table	M8a	
37	WT-5	Working Table	M8a	
38	WT-6	Working Table	M8a	
39	WT-7	Working Table	M8a	
40	WT-8	Working Table	M8a	
41	WT-9	Working Table	M8a	
42	WT-10	Working Table	M8a	
43	WT-11	Working Table	M8a	
44	WT-12	Working Table	M8a	
45	WT-13	Working Table	M8a	
46	WT-14	Working Table	M8a	
47	WT-15	Working Table	M8a	
48	WT-16	Working Table	M8a	
49	WT-17	Working Table	M8a	
50	WT-18	Working Table	M8a	
51	WT-19	Working Table	M8a	
52	WT-20	Working Table	M8a	
53	WT-21	Working Table	M8a	
54	WT-22	Working Table	M8a	Not Available
55	F-1	Frame	M8a	
56	F-2	Frame	M8a	
57	F-3	Frame	M8a	
58	VT-1	Storage Vault	M8a	
59	CR-1	Gate Crane Hoist	M8a	
60	CR-2	Cable Reel (Gate Crane Hoist)	M8a	
61	CR-3	Cable Reel (Gate Crane Hoist)	M8a	
62	RC-1	Receptacle	M8a	
63	LT-1	Incell Light	M8a	
64	CR-1	Jib Crane part 1	M8a	
65	CR-2	Jib Crane part 2	M8a	
66	CR-3	Jib Crane part 3	M8a	
67	CR-4	Jib Crane part 4	Isolation Room	
68	CR-5	Jib Crane part 5	Isolation Room	
69	CR-6	Jib Crane part 6	Isolation Room	
70	SP-1	Shield Plug	Isolation Room	
71	SP-2	Shield Plug	Isolation Room	
72	SP-3	Shield Plug	Isolation Room	
73	IR-1	Wall of the Isolation Room	Isolation Room	
74	IR-2	Wall of the Isolation Room	Isolation Room	
75	IR-3	Wall of the Isolation Room	Isolation Room	
76	RD-1	Cable Reel (Rear Door)	Isolation Room	
77	VT-2	Storage Vault	M8b	
78	F-4	Frame	M8b	
79	M-1	BTSM(Servo Manipulator)	M8a/b	
80	M-2	BTSM	M8a/b	
81	M-3	BTSM	M8a/b	
82	M-4	BTSM	M8a/b	
83	M-5	BTSM	M8a/b	
84	WT-23	Working Table	M8b	
85	WT-24	Working Table	M8b	
86	WT-25	Working Table	M8b	

Smear Test List (Total 97 points)



Target points selection

Smear Test

Smear Test Results

SMEAR SAMPLE ACTIVITY ANALYSIS

Procedure Name : IMEF 반출 - 201303291435

Count Parameters

Group	: A	Count Date	: 2013-03-29
Device	: S5XLB	Count Minutes	: 1.0
Batch Key	: 4,672	Count Mode	: Simultaneous
Selected Geometry	: 1/4" Stainless Steel	Operating Volts	: 1440

Analysis Parameters

Background (cpm)		Efficiency	: Instrument(%)	Source	Removal Fraction
Alpha Rate	0.30	Alpha	: 59.47	0.25	0.50
Beta Rate :	4.62	Beta	: 63.96	0.50	0.50

Carrier ID	Lab. ID	Alpha (kBq/m^2)	2 Sigma (kBq/m^2)	Beta (kBq/m^2)	2 Sigma (kBq/m^2)	Alpha MDA (kBq/m^2)	Beta MDA (kBq/m^2)
19	제염후	< MDA		< MDA		1.01E-001	1.03E-001
20		< MDA		< MDA		1.01E-001	1.03E-001
47		1.05E-001	1.01E-001	< MDA		1.01E-001	1.03E-001
63		< MDA		< MDA		1.01E-001	1.03E-001
86		< MDA		< MDA		1.01E-001	1.03E-001

Reviewed by: ______________________

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Print Date 2013-04-03

Print Time 오전 9:53:55

SMEAR SAMPLE ACTIVITY ANALYSIS

Procedure Name : IMEF 반출 - 201303291437

Count Parameters

Group	: B	Count Date	: 2013-03-29
Device	: S5XLB	Count Minutes	: 1.0
Batch Key	: 4,673	Count Mode	: Simultaneous
Selected Geometry	: 1/4" Stainless Steel	Operating Volts	: 1440

Analysis Parameters

Background (cpm)		Efficiency	: Instrument(%)	Source	Removal Fraction
Alpha Rate	0.30	Alpha	: 59.47	0.25	0.50
Beta Rate :	4.62	Beta	: 63.96	0.50	0.50

Carrier ID	Lab. ID	Alpha (kBq/m^2)	2 Sigma (kBq/m^2)	Beta (kBq/m^2)	2 Sigma (kBq/m^2)	Alpha MDA (kBq/m^2)	Beta MDA (kBq/m^2)
88	ACPF 8셀	< MDA		< MDA		1.01E-001	1.03E-001
89		< MDA		< MDA		1.01E-001	1.03E-001
90		< MDA		< MDA		1.01E-001	1.03E-001
91		< MDA		< MDA		1.01E-001	1.03E-001
92		< MDA		< MDA		1.01E-001	1.03E-001
93		< MDA		< MDA		1.01E-001	1.03E-001
94		< MDA		< MDA		1.01E-001	1.03E-001
95		< MDA		< MDA		1.01E-001	1.03E-001
96		< MDA		< MDA		1.01E-001	1.03E-001
97		< MDA		< MDA		1.01E-001	1.03E-001

Reviewed by: ______________________

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Print Date 2013-03-29

Print Time 오후 3:49:52

Waste Classification and Disposal

All dismantled materials ready for transportation were categorized into combustible and noncombustible materials; the combustible wastes and small noncombustible wastes were put into waste cans, and large noncombustible pieces were stacked in a 2,000-L shielded container.

Three packaging types of waste dismantled from the ACPF; from left to right: individual packaging, large container, and drums

Waste Transportation Process for Disposal

ACPF waste material transportation demand assessment → Consultation with the Waste Management Division for accommodation capacity

Waste material packaging and salt removal

Report (verbal) by the facility manager

Report (verbal and written) by the protection manager

Smear test and decision over disposal (stand-by)

Facility opening (door, 30/5-t crane, trolleys, hatch)

Material disposal

Report by protection manager and vehicle contamination analysis

Waste material transportation

Component analysis sample to the Treatment Division

Treatment history data for each waste material (compiling and making accessible) → Completion of waste material transportation


방사선안전관리절차서
물품반출신청서

Waste material sampling

Worker irradiation history monitoring